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Overview of available estimates and recommended values for MAGNET

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1. Introduction

The land supply elasticity with respect to the land price (land rent) is a key parameter in determining the land supply impacts of economic shocks and policies and the resulting impacts on food prices and food and nutrition security. For example, Elobeid at al., 2011 shows that halving the area expansion elasticities leads to 15% lower land expansion in Brazil necessary for 25% increase in ethanol consumption. However, values for land supply elasticities are rarely available in the literature. Due to lack of reliable time series data on land prices and concerns about the quality of Utilised Agricultural Area data, they are only available estimated for some countries of the world.

In this overview we calculate land supply elasticities for several world regions and countries adapting method proposed in the literature and showing available published estimates.

A comparison between current and new values of MAGNET land elasticities can be found in Appendix C. Appendix D gives a quick operating instruction on how to run MAGNET using the new land set of land supply elasticities in MAGNET.

2. Estimates of land supply elasticities available in the literature

A review of the literature yields econometric estimates of land supply elasticities in respect of land prices only for selected EU countries as shown in Table 1 (Cixous, 2006; Boitier, 2011; Sensor 2006). The estimated elasticities values vary significantly depending on county and source. For instance for Finland the following three values has been found: 4.65, 0.08 and 0.61.

Table 1 - Econometrically estimated land prices elasticities for selected EU countries

	AT	BE	DE	DK	ES	FI	FR	GR	IE	IT	LU	NL	PT
Boitier, 2011	1.19	0.23	1.09	0.23	0.36	4.65	1.42	0.36	0.07	0.32	1.29	0.12	0.30
Cixous, 2006	-	0.07	0.14	0.11	0.16	0.08	0.17	0.11	-	0.15	-	-	-
Sensor, 2006	0.14	0.15	0.16	0.06	0.10	0.61	0.13	0.17	0.04	0.10	-	0.08	0.12
	SE	**UK**	**BG**	**CZ**	**EE**	**HU**	**LT**	**LV**	**MT**	**PL**	**RO**	**SI**	**SK**
Boitier, 2011	2.45	0.10	0.46	0.16	1.21	0.24	0.17	0.42	0.10	0.41	0.38	1.32	0.51
Cixous, 2006	0.08	0.15	-	-	-	-	-	-	-	-	-	-	-
Sensor, 2006	0.49	0.02	-	-	-	-	-	-	-	-	-	-	-

Gurgel at al., 2007 calculates land supply elasticities by dividing the percentage change in agricultural area by percentage change in land price. He calculated the elasticities using 1990–2005 data assuming US percentage price change for all regions[1]. Baldos and Hertel, 2013 extended this approach for additional countries and calculated 5-year elasticities. These are equal to about of one third of Gurgel elasticities. The ratio was set base on US elasticities estimated for 5-yers and 15-years periods by Ahmed at al. 2008. The calculated elasticities are in Table 2.

Several authors estimate land supply elasticities in respect of crop prices or crop returns instead of land prices. However, assuming that crop prices or returns are capitalized in land prices, we can use these elasticities to derive elasticities in respect of land prices. Salhofer (2000) provides the following formula linking land supply elasticity E_l in respect of land price (rental rate of land) with land supply elasticity E_c in respect of the output price of related agricultural commodity:

$$E_l = a/b \cdot E_c \qquad (1)$$

where a is the cost share of land for the agricultural commodity under consideration and b is the fraction of benefits from an increase in the price of commodity that accrue as benefits to landowners. In the long run, b is close to 1 but in medium term Salhofer (2000) proposes values between 1/3 and 2/3.

Table 2 - Calibrated land prices elasticities for different countries and world regions for different periods

Gurgel at al., 2007		Baldos and Hertel, 2013	
USA	0.12	North America	0.04
Canada	0.12		
Japan	0.12		
Australia, New Zealand	0.12		
EU	0.12	Europe & Central Asia	0.04
Eastern Europe	0.12		
Former Soviet Union	0.12		
High Income East Asia	0.38		
China	0.15	East Asia & Pacific	0.04
India	0.31	South Asia	0.10
Indonesia	0.60		
Africa	0.60	Sub-Saharan Africa	0.20
Middle East	0.32	Middle East & North Africa	0.11
Mexico	0.60	Latin America & Caribbean	0.20
Central and South America	0.60		
Rest of the World	0.42		

Land supply elasticities in respect of crop prices of returns available in the literature are presented in Table 3. Barr at al., 2001 employed similar formula as proposed by Gurgel at al., 2007 but used expected returns from land instead of land price. Other authors used econometric methods to estimate elasticities.

[1] Gurgel at al., 2007 expects globally the similar price movements of land around the world because of global commodity trade. Also, he refers to evidence provided by Sutton and Web, 1988.

Table 3 - Prices elasticities with respect to crop prices or returns and derived elasticities with respect of land prices

	Price elasticity for cropland area wrt:		Price elasticity for total agricultural area wrt:		Price elasticity for total agricultural area‡ wrt:	Source for elasticities wrt. crop prices and returns
	Crop prices	**Returns**	**Crop prices**	**Returns**	**Land prices**	**Source**
USA	0.3 0.26-0.33 0.007-0.029	0.005-0.028			0.001-0.028	Scott (2013) Roberts & Schlenker (2011; 2013)† Barr et al. (2011)
Brazil	0.22-0.40 0.38-0.90	0.19-0.44	0.007-0.245	0.030-0.122	0.013-0.052	Roberts & Schlenker (2011; 2013)† Barr et al. (2011)
China	0.030-0.070				0.003-0.008	Roberts & Schlenker (2013)†
India	0.006-0.015				0.001-0.003	Roberts & Schlenker (2013)†
Thailand	0.100-0.250				0.018-0.044	Roberts & Schlenker (2013)†

† Only selected crops included (total of corn, wheat, rice and soybeans).

‡ Own calculations form formula (1) using: (a) crop price elasticities (columns 2 to 5). (b) cost share of land for crops from GTAP 9 database (Badri at al. 2015) (c) assumed fraction 0.5 of benefits from an increase in the price of commodity that accrue as benefits to landowners and (d) assumed ratio of 3.5 of cropland area elasticities to total agricultural area elasticities in the long run (Barr et al., 2011 results for Brazil).

3. MAGNET estimates of land supply elasticities

Elasticities based on the original MAGNET land supply function

The original MAGNET land supply functional form makes it possible to derive land supply elasticities in the easy way. The assumed function is:

$$L = A - B/P \quad (2)$$

where L is land supply, P is the real land price, A is the maximum available agricultural land area (the land asymptote), and B is a positive parameter. The resulting land supply elasticity E in respect of land price is defined as:

$$E = A/L - 1 \quad (3)$$

We used data provided by IMAGE model (Stehfest, at al., 2014) for almost all world countries to calculate these elasticities. Elasticities for IMAGE model regions and major countries are presented in Table 4. According to this formula, specific land supply elasticity depends upon the ratio of the asymptote to land used for agriculture, and therefore it crucially depends on estimates of maximum available agricultural land area, A, which are subject of many uncertainties (Mandryk et al. 2015). The elasticity can differ, depending on estimates of land availability estimates, and often results in high land supply elasticities which are inconsistent with observed of agricultural area changes.

Elasticities calculated from agricultural land and return time series

We also calculated land supply elasticities adapting method used by Gurgel at al. (2007) and Barr et al. (2011) for several world regions and countries. We calculated land supply elasticities directly from the observed percentage changes in agricultural land and percentage changes in total return of agriculture per unit of agricultural land. In this approach, we assume that returns from agricultural production are capitalized in land prices in the long run and therefore percentage changes in return of agriculture per unit of agricultural land are good proxies for unobserved percentage changes in land prices.

We use two alternative data sources to calculate these elasticities:

- CAPRI database
- FAO and World bank data

CAPRI database

The CAPRI database (Britz and Witzke, 2014) includes time series of land balances, prices of agricultural products, yields per hectare and gross margins per hectare (both excluding and including agricultural subsidies) for agricultural activities in the EU Member States, Norway, Western Balkan countries and Turkey (list of countries is presented in Appendix A). To convert to real prices, the historical development of the consumer price index is used.

As explained above, we estimate the land supply elasticities directly from the observed changes in Utilised Agricultural Area (UAA) and changes in average gross margins, including subsidies (all measured in real prices) per unit of agricultural land. We calculate land supply elasticities over different time periods. This is mainly steered by the introduction of hectare premiums in 1993 in the EU15, and farm payments and single area payments in 2003/2004 in EU15 and EU12 respectively. The percentage change in utilised agricultural area is corrected for the observed long term trend in the supply of utilised agricultural area. Appendix A gives the list of agricultural activities included in the calculation of available agricultural land and the average gross margin, including agricultural subsidies per ha per period per country. Average agricultural land and gross margin are calculated for the periods 2000 to 2003 and 2006 to 2010[2].

It is important to note that:

A. positive land supply elasticities are especially due to decreasing agricultural area and decreasing gross margins;
B. if land supply elasticity becomes negative, its value is put equal to 0.015.

[2] Some countries are treated a little differently. Land supply elasticity in Germany includes fallow land as agricultural land. This is due to uncertainties concerning fallow land in Germany in the database. For Turkey a different period is used namely from 2004 to 2006 and from 2008 to 2010.

FAO and World bank data

Total agricultural area (in 1000 ha) and agricultural value added (in constant 2005 US$) was used to calculate elasticities using data from the FAO[3] and World Bank World Development Indicators (WDI) database[4]. Agricultural value added was divided by agricultural area to compute value added per hectare to use as a proxy for total agricultural returns.

The land supply elasticities for individual countries are calculated directly from the data using periods that can be different per individual country depending on the data quality. Another reason to use different periods is that we expect a positive elasticity so land and value added per hectare needs to move in the same direction in the chosen period. For all countries for which data do not show an increase of agricultural area since 2000 and at the same time show increase of agricultural return (e.g. USA, South Korea, Japan, Oceania, Australia and India), we choose elasticity 0.015. This elasticity is close to zero but at the same time does not make the land supply function too vertical which could create problems when solving a model.

In

[3] http://faostat.fao.org/
[4] http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

Table 4, we present calculated land supply elasticities for IMAGE and major countries. Individual country results are presented in the next section. For Europe, agricultural land and value added moves in different directions according FAO and World Bank data. The agricultural land is decreasing and at the same time agricultural value added is increasing. This makes it impossible to calculate positive elasticities. Therefore to obtain land supply elasticities for Europe, CAPRI data have been used.

Table 4 - Land supply elasticities for IMAGE model regions and major countries

	Elasticity from the formula A/L-1	Acreage elasticity wrt total value added agriculture (adapted "Gurgel" approach)	Source of adapted "Gurgel" elasticities	Comment
IMAGE regions				
Canada	0.595	0.048	FAO/WB	
USA	0.232	0.015		No positive elasticity found
Mexico	0.228	0.103	FAO/WB	
Rest of Central America	0.421	0.131	FAO/WB	
Brazil	0.596	0.120	FAO/WB	
Rest of Southern America	0.501	0.376	FAO/WB	
Northern Africa	0.017	0.016	FAO/WB	
Western Africa	0.263	0.096	FAO/WB	
Eastern Africa	0.188	0.081	FAO/WB	
Southern Africa	0.616	0.101	FAO/WB	
EU16	0.319	0.043	CAPRI	
Rest of Western Europe	0.404	0.061	CAPRI	
EU12	0.197	0.024	CAPRI	
Rest of Eastern Europe	0.171	0.062	CAPRI	
Turkey	0.319	0.090	FAO/WB	
Ukraine Plus	0.155	0.034	FAO/WB	
Asia-Stan Countries	0.008	0.034	FAO/WB	
Russia Plus	0.473	0.036	FAO/WB	
Middle East	0.048	0.015	FAO/WB	
India Plus	0.153	0.019	FAO/WB	
Korea	0.000	0.015		No positive elasticity found
China Plus	0.067	0.020	FAO/WB	
South East Asia	1.201	0.401	FAO/WB	
Indonesia Plus	1.357	0.620	FAO/WB	
Japan	0.000	0.015		No positive elasticity found
Oceania	0.161	0.015		No positive elasticity found
Selected countries				
Australia	0.126	NA		No positive elasticity found
China	0.079	0.021	FAO/WB	
India	0.183	NA		No positive elasticity found
Indonesia	1.357	0.620	FAO/WB	
Russia	0.485	0.037	FAO/WB	
Ukraine	0.091	0.024	FAO/WB	
Belarus	0.469	0.038	FAO/WB	
Argentina	0.263	0.685	FAO/WB	

4. Land supply elasticities selected for MAGNET

Because of relatively limited documentation and literature concerning land supply elasticities the choice of these elasticities for medium and long term projections is rather subjective matter. This can be illustrated by choice of elasticities used in MIRAGE model. MIRAGE, Updated Version of the Model for Trade Policy Analysis (Decreux and Valin, 2007), uses land supply elasticities 0.25 for land constrained countries and 1 for other countries. This model was, e.g., used by Bouët and Laborde, 2010 for evaluation of Doha trade liberalization proposals. In the MIRAGE-BIOF model used in the study "European Union and United States Biofuel Mandates, Impacts on World Markets (Al-Riffai P., Dimaranan B. and Laborde D., 2010), the land supply elasticity was set at 0.02 for EU and USA and at 0.035 for Brazil. In the similar study by the same authors (Al-Riffai P., Dimaranan B. and Laborde D., 2010A), the varying by region elasticities between 0.05 and 0.1 are used. Finally, in another study using MIRAGE-BIOF model (Laborde and Valin, 2012) elasticities between 0.01 and 0.05 are employed. As the authors of these papers point out, the land supply elasticity is uncertain parameter and they advise to conduct sensitivity analyses around its chosen value in the simulation experiment.

This overview of land supply elasticities available in literature suggests that land supply elasticities are rather low. This is confirmed by statistical data which shows that agricultural areas for majority of countries increase very slowly or even decrease since 2000; while agricultural value added per unit of agricultural area often increases significantly. Our choice of land supply elasticities for MAGNET is as follows:

We chose elasticities calculated from agricultural land and return time series (as described for previous section) for all countries for which data were available.

We choose elasticity 0.015 for countries that are analysed but for which data do not show an increase of agricultural area since 2000 and at the same time show increase of agricultural return (e.g. European countries, USA, South Korea, Japan, Oceania, Australia and India). This elasticity is close to zero but at the same time does not make the land supply function too vertical which could create problems when solving a model.

For selected countries for which the elasticities cannot be calculated because of lack of agricultural land and return time series the following approach was followed. First the ratio between 'our' land supply elasticity (see Appendix B) and the elasticity using formula (3) for neighbouring countries was calculated. Next, this ratio is multiplied with the selected country specific land supply elasticity using formula (3). Selected countries are especially located in Western and Southern Africa, and Rest of South America. These three IMAGE regions are characterised by relatively high land supply elasticity from the formula (A/L-1), while elasticities based on FAO and World Bank data elasticity was judged too low. The selected countries are Venezuela, El Salvador, Côte d'Ivoire, Gambia, Ghana, Liberia, Congo and Tanzania.

We choose elasticity 0.015 for all remaining, mostly small, countries. The land supply elasticities for all world countries are presented in the Appendix B.

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6. Appendix A. Countries and agricultural activities in CAPRI used to calculated land supply elasticities

Countries		Agricultural activities	
BL	Belgium	SWHE	soft wheat
DK	Denmark	DWHE	durum wheat
DE	Germany	RYEM	rye
EL	Greece	BARL	barley
ES	Spain	OATS	oats
FR	France	MAIZ	grain maize
IR	Ireland	OCER	other cereals
IT	Italy	RAPE	rape
NL	Netherlands	SUNF	sunflower
AT	Austria	SOYA	soya
PT	Portugal	OOIL	other seed production activities for the oil
SE	Sweden	OIND	other industrial crops production activity
FI	Finland	NURS	nurseries
UK	UK	FLOW	flowers
CY	Cyprus	OCRO	other crops
CZ	Cyprus	NECR	new energy crops
EE	Estonia	MAIF	fodder maize
HU	Hungary	ROOF	fodder root crops
LT	Lithuania	OFAR	fodder other on arable land
LV	Latvia	GRAE	grassland extensive
MT	Malta	GRAI	grassland intensive
PL	Poland	PARI	paddy rice
SI	Slovenia	OLIV	olive
SK	Slovak Republic	PULS	pulses
BG	Bulgaria	POTA	potatoes
RO	Romania	SUGB	sugar beets
AL	Albania	TEXT	flax and hemp
MK	Macedonia	TOBA	tobacco
CS	Serbia	TOMA	tomatoes
MO	Montenegro	OVEG	other vegetables
HR	Croatia	APPL	apples, pears and peaches
BA	Bosnia and	OFRU	other fruits
KO	Kosovo	CITR	citrus
NO	Norway	TAGR	table grapes
TU	Turkey	TABO	table olives
		TWIN	wine production

7. Appendix B. Land supply elasticities

Australia	0.015	Latvia	0.014
Christmas Island	0.015	Lithuania	0.009
Cocos (Keeling) Islands	0.015	Luxembourg	0.015
Heard Island and McDonald Islands	0.015	Malta	0.015
Norfolk Island	0.015	Netherlands	0.015
New Zealand	0.015	Poland	0.141
American Samoa	0.015	Portugal	0.015
Cook Islands	0.015	Slovakia	0.015
Fiji	0.015	Slovenia	0.015
French Polynesia	0.015	Spain	0.015
Guam	0.015	Sweden	0.015
Kiribati	0.015	United Kingdom	0.015
Marshall Islands	0.015	Switzerland	0.015
Micronesia, Federated States of	0.015	Bouvet Island	0.015
Nauru	0.015	Norway	0.055
New Caledonia	0.015	Svalbard and Jan Mayen	0.055
Niue	0.015	Iceland	0.015
Northern Mariana Islands	0.015	Liechtenstein	0.015
Palau	0.015	Albania	0.148
Papua New Guinea	0.015	Bulgaria	0.015
Pitcairn	0.015	Belarus	0.024
Samoa	0.015	Croatia	0.040
Solomon Islands	0.015	Romania	0.041
Tokelau	0.015	Russian Federation	0.037
Tonga	0.015	Ukraine	0.038
Tuvalu	0.015	Moldova, Republic of	0.015
United States Minor Outlying Islands	0.015	Andorra	0.015
Vanuatu	0.015	Bosnia and Herzegovina	0.022
Wallis and Futuna	0.015	Faroe Islands	0.015
China	0.021	Gibraltar	0.015
Hong Kong	0.015	Guernsey	0.015
Japan	0.015	Holy See (Vatican City State)	0.015
Korea, Republic of	0.015	Isle of Man	0.015
Taiwan, Province of China	0.015	Jersey	0.015
Korea, Democratic People's Republic of	0.015	Macedonia, the former Yugoslav Republic of	0.025
Macao	0.015	Monaco	0.015
Mongolia	0.015	Montenegro	0.015
Cambodia	0.214	San Marino	0.015
Indonesia	0.620	Serbia	0.077
Lao People's Democratic Republic	0.015	Kazakhstan	0.041
Malaysia	0.350	Kyrgyzstan	0.015
Philippines	0.389	Tajikistan	0.015

Singapore	0.015	Turkmenistan	0.015
Thailand	0.493	Uzbekistan	0.015
Viet Nam	0.917	Armenia	0.015
Brunei Darussalam	0.015	Azerbaijan	0.015
Myanmar	0.015	Georgia	0.015
Timor-Leste	0.015	Iran, Islamic Republic of	0.015
Bangladesh	0.015	Kuwait	0.015
India	0.015	Turkey	0.090
Pakistan	0.058	Bahrain	0.015
Sri Lanka	0.015	Iraq	0.015
Afghanistan	0.015	Israel	0.015
Bhutan	0.015	Jordan	0.015
Maldives	0.015	Lebanon	0.015
Nepal	0.015	Oman	0.015
Canada	0.048	Palestinian Territory, Occupied	0.015
United States	0.015	Qatar	0.015
Mexico	0.103	Saudi Arabia	0.015
Bermuda	0.015	Syrian Arab Republic	0.015
Greenland	0.015	United Arab Emirates	0.015
Saint Pierre and Miquelon	0.015	Yemen	0.015
Argentina	0.684	Egypt	0.015
Bolivia, Plurinational State of	0.060	Morocco	0.015
Brazil	0.120	Tunisia	0.028
Chile	0.015	Algeria	0.014
Colombia	0.065	Libyan Arab Jamahiriya	0.015
Ecuador	0.054	Western Sahara	0.015
Paraguay	0.228	Nigeria	0.074
Peru	0.140	Senegal	0.355
Uruguay	0.611	Benin	0.208
Venezuela, Bolivarian Republic of	0.142	Burkina Faso	0.217
Falkland Islands (Malvinas)	0.015	Cape Verde	0.015
French Guiana	0.015	Côte d'Ivoire	0.107
South Georgia and the South Sandwich Islands	0.015	Gambia	0.044
Suriname	0.104	Ghana	0.119
Costa Rica	0.015	Guinea	0.201
Guatemala	0.274	Guinea-Bissau	0.183
Nicaragua	0.239	Liberia	0.474
Panama	0.123	Mali	0.058
Belize	0.045	Mauritania	0.015
El Salvador	0.068	Niger	0.015
Honduras	0.287	Saint Helena	0.015
Anguilla	0.015	Sierra Leone	0.721
Antigua and Barbuda	0.015	Togo	0.133
Aruba	0.015	Cameroon	0.187
Bahamas	0.015	Central African Republic	0.048

Barbados	0.015	Chad	0.048
Cayman Islands	0.015	Congo	0.048
Cuba	0.015	Equatorial Guinea	0.048
Dominica	0.015	Gabon	0.048
Dominican Republic	0.015	Sao Tome and Principe	0.048
Grenada	0.015	Angola	0.018
Haiti	0.015	Congo, the Democratic Republic of the	0.113
Jamaica	0.015	Ethiopia	0.219
Montserrat	0.015	Madagascar	0.045
Netherlands Antilles	0.015	Malawi	0.454
Puerto Rico	0.015	Mauritius	0.015
Saint Kitts and Nevis	0.015	Mozambique	0.034
Saint Lucia	0.015	Tanzania, United Republic of	0.308
Saint Vincent and the Grenadines	0.015	Uganda	0.831
Trinidad and Tobago	0.015	Zambia	0.291
Turks and Caicos Islands	0.015	Zimbabwe	0.334
Virgin Islands, British	0.015	Burundi	0.185
Virgin Islands, U.S.	0.015	Comoros	0.625
Austria	0.027	Djibouti	0.015
Belgium	0.035	Eritrea	0.015
Cyprus	0.112	Kenya	0.028
Czech Republic	0.015	Mayotte	0.015
Denmark	0.015	Rwanda	0.263
Estonia	0.065	Seychelles	0.015
Åland Islands	0.015	Somalia	0.015
Finland	0.015	Sudan	0.015
France	0.015	Botswana	0.009
Guadeloupe	0.015	South Africa	0.038
Guyana	0.015	Lesotho	0.023
Martinique	0.015	Namibia	0.015
Réunion	0.015	Swaziland	0.015
Germany	0.218	Antarctica	0.015
Greece	0.015	British Indian Ocean Territory	0.015
Hungary	0.016	French Southern Territories	0.015
Ireland	0.015	South Sudan	0.015
Italy	0.025		

8. Appendix C. Old and new land supply elasticities in AgriFood2030

Region or country	Code	Elasticity	
		Old	New
United Kingdom	UK	0.013	0.015
Netherlands and Sweden	NLSWE	0.413	0.015
Denmark	DK	0.231	0.015
Germany	GER	0.228	0.218
Austria	AUT	0.117	0.027
France	FRA	0.109	0.015
Ireland	IRE	0.028	0.015
Italy	ITA	0.108	0.025
Spain	SPA	0.048	0.015
Poland	POL	0.285	0.141
Rest of the EU27	RoEU27	0.234	0.024
Croatia	CRO	0.964	0.040
USA	USA	0.846	0.015
Canada	CAN	6.877	0.048
Mercosur	MERC	1.627	0.311
Russian Federation	RUS	3.545	0.037
China	CHN	0.158	0.021
India	IND	0.006	0.015
Japan	JPN	0.053	0.015
Australia & New Zealand	AUSNZ	0.379	0.015
Middle East & North Africa	MENA	0.184	0.022
Sub-Saharan Africa	SSA	0.878	0.093
Rest of the World	ROW	0.630	0.106

9. Appendix D. New set of land supply elasticities in MAGNET

New land supply elasticities are introduced into new AgriFood2030 model version called MAGNET_3_09_AgriFood2030D committed on the svn sever. To introduce these elasticities into the model, \land\AggregateLandSupplyElasticity box should be checked in Database tab, Chose includes. Otherwise, program will not work.

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